LANSCE
Los Alamos Neutron Science Center

Research Proposal for the use of Neutron Science Facilities

☐ **Fast Access** ☐ **Joint CINT Proposal**

Proposal Number: 20111553
Submission Number: S1573
Date Received: 03/14/11

Program Advisory Subcommittee: Defense-related Nuclear Science
Focus Area:

Flight Path/Instrument: 1FP14 / DANCE
Estimated Beam Time (days): 28
Days Recommended: 0
Dates Desired: Flexible dates, will be negotiate
Impossible Dates: June, July

TITLE
Neutron Capture Cross Section and Fission Measurement of 238Pu at DANCE

☐ Continuation of Proposal #:

☐ Ph.D Thesis for:

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RESEARCH AREA

- ☐ Biological and Life Science
- ☐ Chemistry
- ☐ National Security
- ☐ Earth Sciences
- ☐ Engineering
- ☐ Environmental Sciences
- ☒ Nuc. Physics/chemistry
- ☐ Astrophysics
- ☐ Few Body Physics
- ☐ Fund. Physics
- ☐ Elec. Device Testing
- ☐ Dosimetry/Med/Bio
- ☐ Earth/Space Sciences
- ☐ Materials Properties/Test
- ☐ Other:
- ☐ Mat'l Science (incl Cond Matter)
- ☐ Medical Applications
- ☐ Nuclear Physics
- ☐ Polymers
- ☐ Physics (Excl Condensed Matter)
- ☐ Instrument Development
- ☐ Neutron Physics
- ☒ Fission
- ☒ Reactions
- ☐ Spectroscopy
- ☐ Nuc. Accel. Reactor Eng.
- ☐ Def. Science/Weapons Physics
- ☐ Radiography
- ☐ Threat Reduction/Homeland Sec.
- ☐ Other:

FUNDING AGENCY

- ☐ DOE/BES
- ☐ DOE/OBER
- ☒ DOE/NNSA
- ☐ DOE/NE
- ☐ DOE/SC
- ☐ DOE/Other
- ☐ DOD
- ☐ NSF
- ☐ Industry
- ☐ NASA
- ☐ NIH
- ☐ Foreign:
- ☐ Other US Gov't:
- ☐ Other:

PUBLICATIONS

Publications:

Measurement of the ^{157}Gd(n,${\gamma}$) reaction with the DANCE array. Submitted to PRC in Feb, 2011.

Abstract: S1361_proposal.pu2.pdf

By electronic submission, the Principal Investigator certifies that this information is correct to the best of their knowledge.

Safety and Feasibility Review *(to be completed by LANSCE Instrument Scientist/Responsible)*

☐ **No further safety review required** ☐ **To be reviewed by Experiment Safety Committee**

☐ **Approved by Experiment Safety Committee, Date:**

Recommended # of days:	**Change PAC Subcommittee and/or Focus Area to:**	**Change Instrument to:**

Comments for PAC to consider:

Instrument scientist signature: **Date:**

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LLNL-PROP-425111

Neutron Capture Cross Section and Fission-Gamma Measurement of ^{241}Pu at DANCE

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1 Introduction

The magnitude and energy dependence of ^{241}Pu(n,γ) cross section is important to the nuclear forensics and stockpile stewardship program. The energy-multiplicity distribution of fission related γ-rays is needed for plutonium fuel cycle initiatives in the advanced nuclear reactors. We propose to measure the neutron capture cross section for ^{241}Pu in the incident neutron energy interval 0.025 eV to 100 keV with the 10% accuracy at 10 keV, and the γ-ray energy-multiplicity distribution from fission. Spectroscopy will be done with the DANCE array on flight path 14 at the Lujan center at LANSCE. A 70% enriched target of ^{241}Pu will be prepared by electrodeposition on Ti and characterized at Lawrence Livermore National Laboratory (LLNL). This experiment will be performed with the DANCE Fission Counter (DFC) placed inside DANCE to tag fission events and separate neutron capture γ-rays from fission related γ-rays. We request 16 days of beam time for this target to collect counting statistics for the 10% cross section accuracy at 10 keV neutron energy. An additional 3 days of beam time are necessary for measuring background, γ-ray energy calibration, and neutron flux determination. The total beam time request is 19 days.

2 Motivation

The ^{241}Pu(n,γ) reaction is important in nuclear forensics and stockpile stewardship program. The ^{241}Pu(n,f) reaction and fission related γ-ray energy-multiplicity distribuion are necessary for the plutonium fuel cycle in the advanced reactor design program. This proposal aims for measuring the ^{241}Pu(n,γ) cross section with the 10% accuracy at 10 keV. Using the DANCE array coupled with the DANCE Fission Counter we can measure the ^{241}Pu(n,γ) and ^{241}Pu(n,f) cross sections in the incident neutron energy range of E_n = 0.025 eV to 100 keV.

The existing experimental neutron capture data on ^{241}Pu (Fig. 2) is inconsistent with evaluations at the 1-eV, 3-eV, 6-eV energies where even the presence of resonances is questioned. Also they are limited number of cross section points with 50% accuracy at 10 keV.

Some cross section points were deduced from the ^{241}Pu(n,tot) cross section. Using DANCE and DFC we can directly measure neutron capture and fission cross sections in the neutron energy range from thermal to 100 keV. Using DFC for fission tagging we can determine energy-multiplity distribution of fission related γ-rays. The ^{241}Pu(n,γ) and ^{241}Pu$(n,f\gamma)$ data are needed for nuclear forensics and advanced nuclear reactor design correspondingly.

3 Experiment Details

We propose to measure the ^{241}Pu$(n\gamma)$ cross section in the neutron energy range of E_n = 0.02 eV – 100 keV using the DANCE array coupled with DFC at flight path 14 of the Lujan Scattering Center at LANSCE. We will produce a target that contains 70.71% of ^{241}Pu and the rest are other Pu isotopes (Tab. 1) Currently the 70.71% enriched ^{241}Pu contains 28% of ^{241}Am as a daughter

Table 1: Isotopic composition of the ^{241}Pu target as of Decay Date 29/06/2009.

Isotope	Target [%]
^{238}Pu	0.06
^{239}Pu	4.05
^{240}Pu	15.5
^{241}**Pu**	**70.71**
^{242}Pu	9.7

product of the β^--decay; this isotope will be chemically removed from ^{241}Pu. The target will be a $\sim$400 $\frac{\mu g}{cm^2}$ aerial thick layer of Pu blend listed in Tab. 1

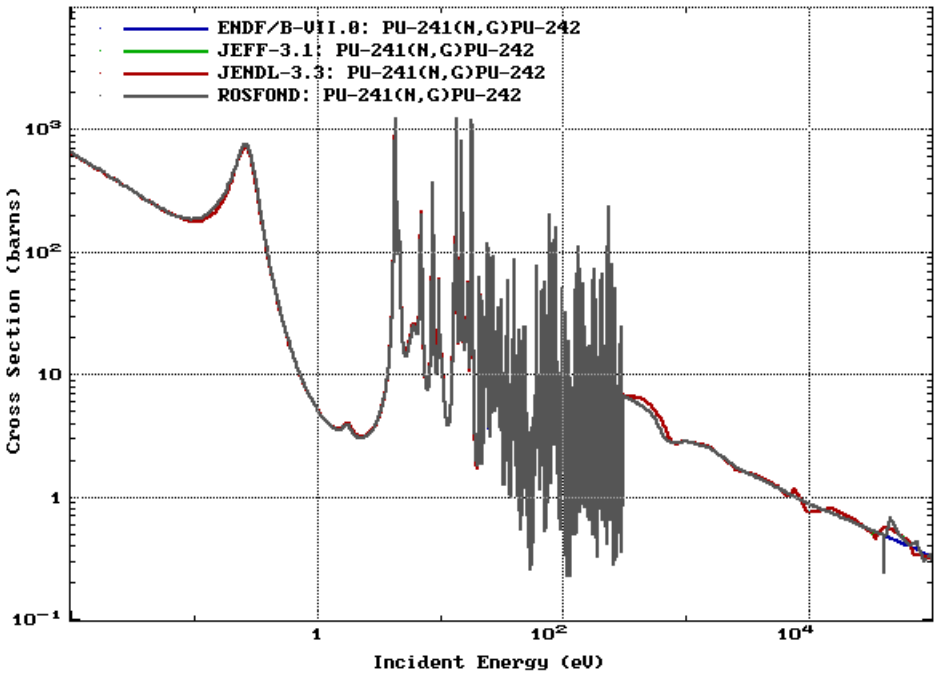

Figure 1: Evaluated neutron capture data for ^{241}Pu.

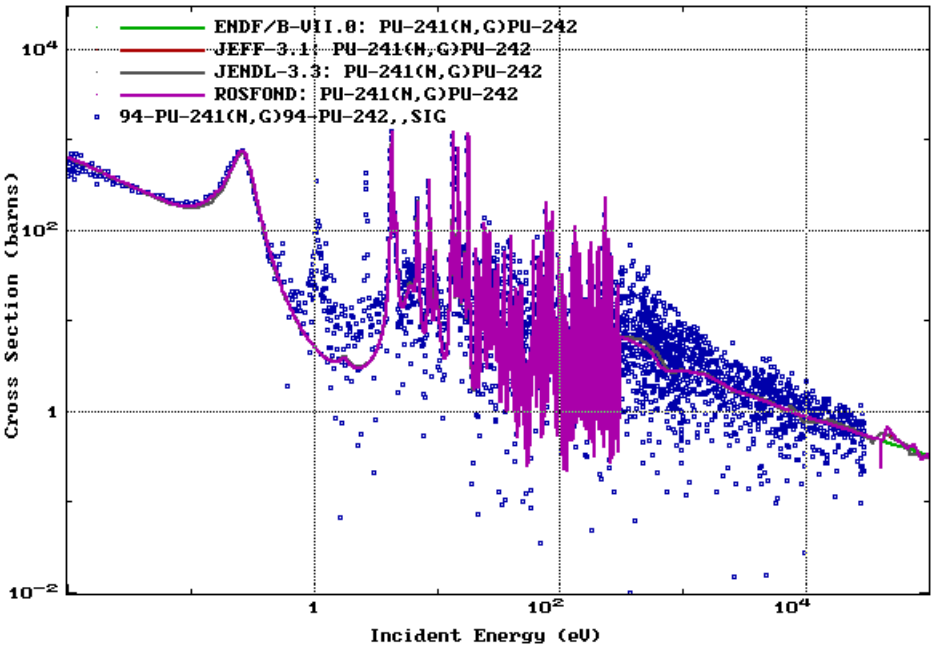

Figure 2: Experimental ^{241}Pu(n,γ) cross section.

deposited onto 3 μm thick Ti foil, resulting in $\sim$154 μg of the Pu blend on one side of the foil. The double side depositions will be covered with aluminized mylar to reduce the chances of contamination. The total amount of the Pu deposition in the target will be $\sim$308 μg. The target will be mounted inside the radioactive target holder and placed inside DFC, this assembly will be shipped to LANSCE to be placed inside DANCE.

The half-life $T_{1/2}(^{241}Pu)$ = 14.3 y, which results in specific activity of the target $\sim$ 22.3 mCi β^--activity. The energies of the dominant γ-rays of the ^{241}Pu decay and the X-rays from slowing down α-particles are below the 150-keV DANCE detection threshold. The β-activity of the target will not pose a significant background. The activity of this target presents handling and safety radiological challenges. We will mitigate potential hazards based on previous experience with several Am targets that require similar handling procedures as Pu isotopes. In the past years successfull IWD's were implemented for Am targets; the IWD for ^{241}Pu is under preparation.

During measurements of the ^{241}Pu target we anticipate background to be made of the following major components:

- elastic scattering and neutron capture from the Ti backing foils;
- neutron capture, elastic scattering, and fission from ^{239}Pu. The Q-values of ^{239}Pu(n,γ) and ^{241}Pu(n,γ) are 6.534 and 6.309 MeV respectively, which is less than the γ-energy resolution of DANCE;
- elastic scattering from ^{241}Pu;

In order to address these background issues we need to measure Ti and ^{208}Pb targets at DANCE. The fission and capture separation will be done using DANCE and DFC. Based on our previous experience the ^{208}Pb target will well serve as a simulator for the (n, el) reactions on Ti, ^{239}Pu, and ^{241}Pu. We anticipate the other collaborators will collect the neutron capture and fission data on ^{239}Pu, thus we should be able to use this data for background subtraction in the ^{241}Pu data analysis.

We need beam time for γ-ray energy calibration and neutron flux determination. Measurement with a ^{197}Au target will help to determine neutron flux, and an ^{88}Y target – to determine the γ-ray energy calibration.

4 Beam Time Request

The number N_γ of capture events is given by:

$$N_\gamma = \Phi_n S_{Pu} \Delta E_n T \sigma_{n,\gamma} N_{Pu} E_{n,\gamma} \quad (1)$$

- $\Phi_n = 1\ \frac{n}{s \cdot cm^2 \cdot eV}$ (the neutron flux);
- $S_{Pu} = 0.38$ cm^2 (the area of the ^{241}Pu deposition);
- $\Delta E_n = 1000$ eV (the neutron energy bin at $E_n = 10$ keV);
- $T = 16$ days (the exposure time);
- $\sigma_{n,\gamma} = 3$ b (the estimated ^{241}Pu(n,γ) cross section at $E_n = 10$ keV);
- $N_{Pu} = \frac{M_{Pu} C_{Pu} N_a}{A_{Pu}}$ (the number of ^{238}Pu nuclei);
- $M_{Pu} = 308\ \mu g$ (the total mass of Pu deposition);
- $C_{Pu} = 0.7071$ (the ^{241}Pu isotope abundance in the target material);
- $N_a = 6.02 \cdot 10^{23}$ (the Avogadro number);
- $A_{Pu} = 238$ (the atomic mass of ^{238}Pu);
- $E_{n,\gamma} = 0.25$ (the efficiency of utilizing capture events in data analysis);

We want to measure the cross section at $E_n = 10$ keV with the 10% energy resolution ($\Delta E_n = 1$ keV at $E_n = 10$ keV) and 10% error bar; efficiency of the data analysis cuts varies within 10 – 25%. Collecting 200 neutron capture events at these conditions (results in 10% accuracy in cross sections), requires 16 continuous days of beam time, and additional 3 days for background runs, a total beam request of 19 days.

References

[1] S.F.Mughabghab, "Atlas of Neutron Resonances, Resonance Parameters and Thermal Cross Sections, Z=1–100", Elsevier, 2006.

[2] ENDF/B-VII, Nuclear National Data Center, www.nndc.bnl.gov

[3] "Neutron Capture Cross Section of ^{241}Am".
M. Jandel, T.A. Bredeweg, E.M. Bond, M.B. Chadwick, R.R. Clement, A. Couture, J.M. O'Donnel, R.C. Haight, T. Kawano, R. Reifarth, R.S. Rundberg, J.L. Ullmann, D.J. Vieira, J.B. Wilhelmy, J.M. Wouters, U. Agvaanlusan, W.E. Parker, C.Y. Wu, J.A. Becker.
Physical Review **C** 78, 034609 (2008).